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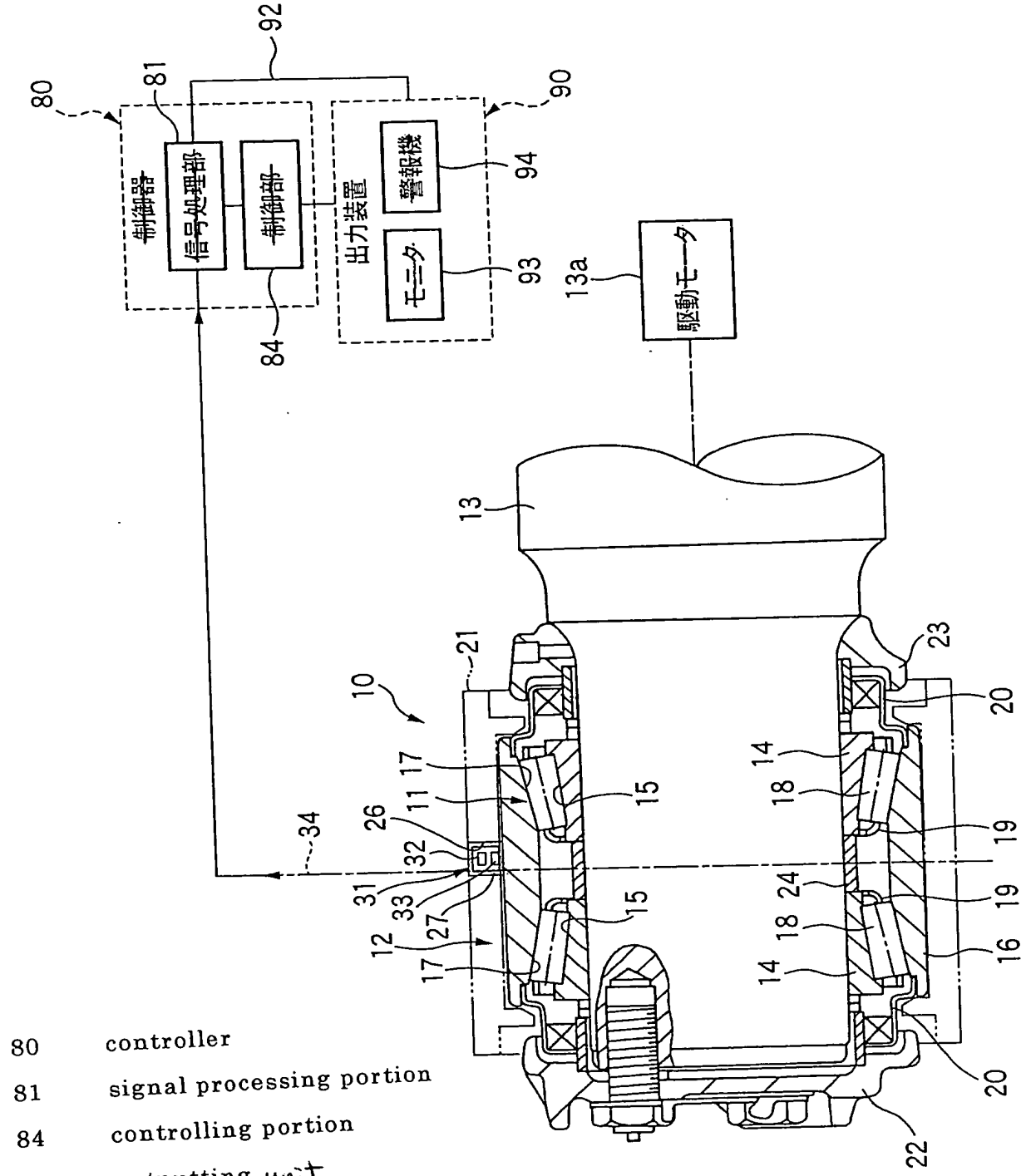
図1 Fig. 1



80 controller

81 signal processing portion

84 controlling portion

90 outputting unit

93 monitor

94 alarm

13a drive motor

[Fig. 2]

40 rotational speed sensor
33 temperature sensor
32 vibration sensor
51 temperature measured value analyzing portion
50 vibration measured value analyzing portion
36 characteristic frequency storing portion
35 filter portion (for extracting predetermined frequency band)
37 envelope processing portion
38 frequency analyzing portion
39 comparing and checking portion
41 theoretical frequency calculating portion
42 abnormality determining portion (presence or absence of abnormality, degree of damage, specification of portion)
90 outputting unit

Fig. 2 (図2)

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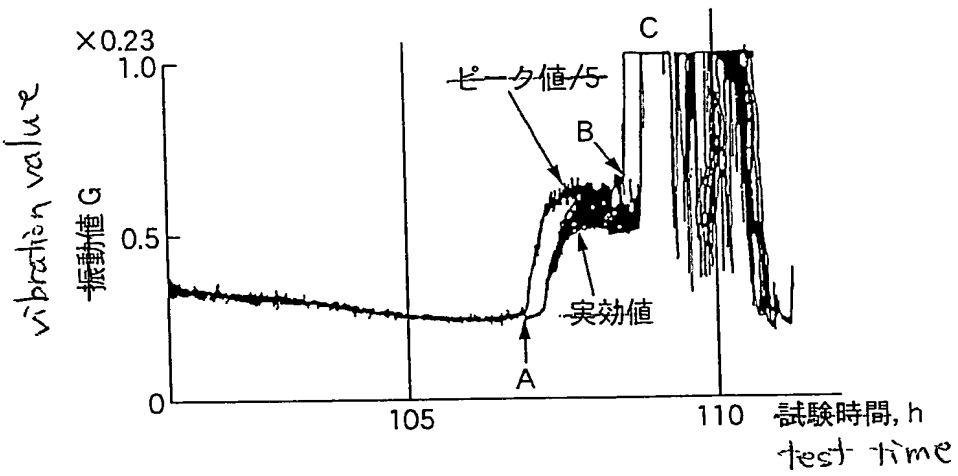
Fig. 3

~~[図3]~~

peak value/5



~~[図4]~~

Fig. 4

temperature at outer diameter surface of outer ring

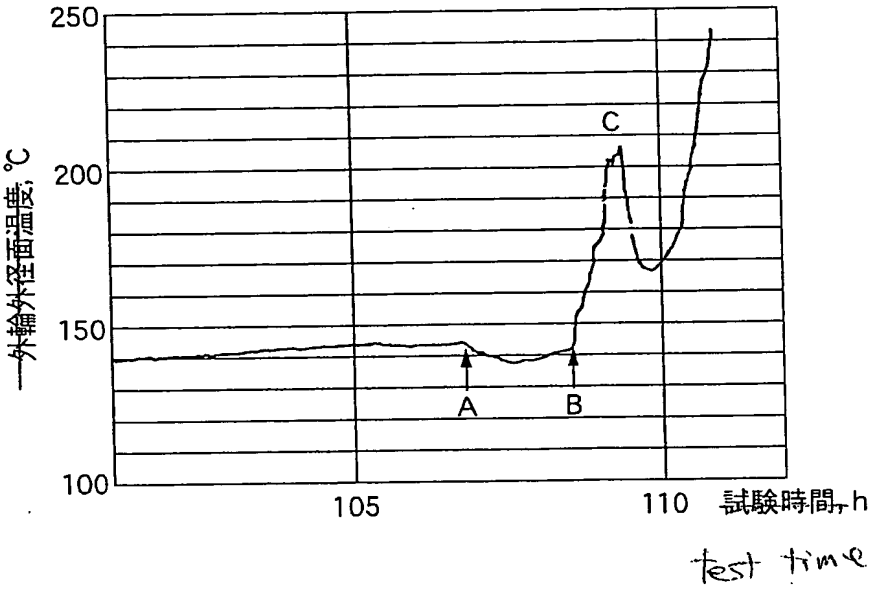


Fig. 5

~~[図5]~~

~~軸受の部位~~ (Sx) portion of bearing	~~部位に対応する周波数~~ frequency corresponding to the portion
~~内輪~~ (Si) inner ring	$Zfi=\frac{fr}{2}\left(1+\frac{Da}{dm}\cdot\cos\alpha\right)Z$
~~外輪~~ (So) outer ring	$Zfc=\frac{fr}{2}\left(1-\frac{Da}{dm}\cdot\cos\alpha\right)Z$
~~転動体~~ (Sb) rolling element	$2fb=fr\left(1-\frac{Da^2}{dm^2}\cdot\cos^2\alpha\right)\frac{dm}{Da}$
~~保持器~~ (Sc) retainer	$fc=\frac{fr}{2}\left(1-\frac{Da\cdot\cos\alpha}{dm}\right)$

fr : ~~内輪(外輪)回転速度~~ [Hz]　Z : ~~転動体の数~~
fc : ~~保持器回転速度~~ [Hz]　fi : fr−fc
fb : ~~転動体自転速度~~ [Hz]　Da : ~~転動体直径~~ [mm]
dm : ~~転動体ピッチ円径~~ [mm]　α : ~~接触角~~ [rad]

fr: inner (outer) ring rotational speed [Hz]

fc: retainer rotational speed [Hz]

fb: rolling member rotating speed [Hz]

dm: rolling element pitch circle diameter [mm]

Z: number of rolling element

Da: rolling member diameter [mm]

α: contact angle [rad]

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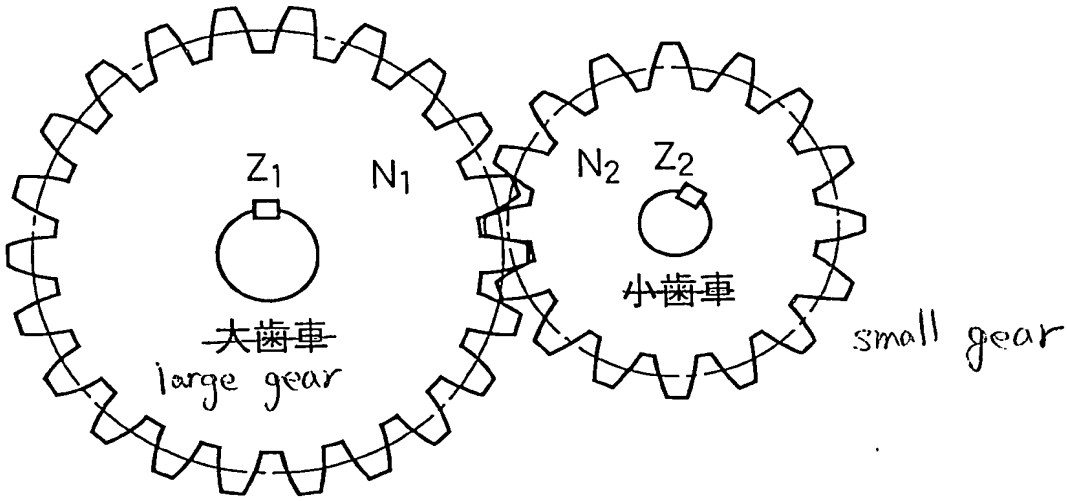
~~[図6]~~ Fig. 6

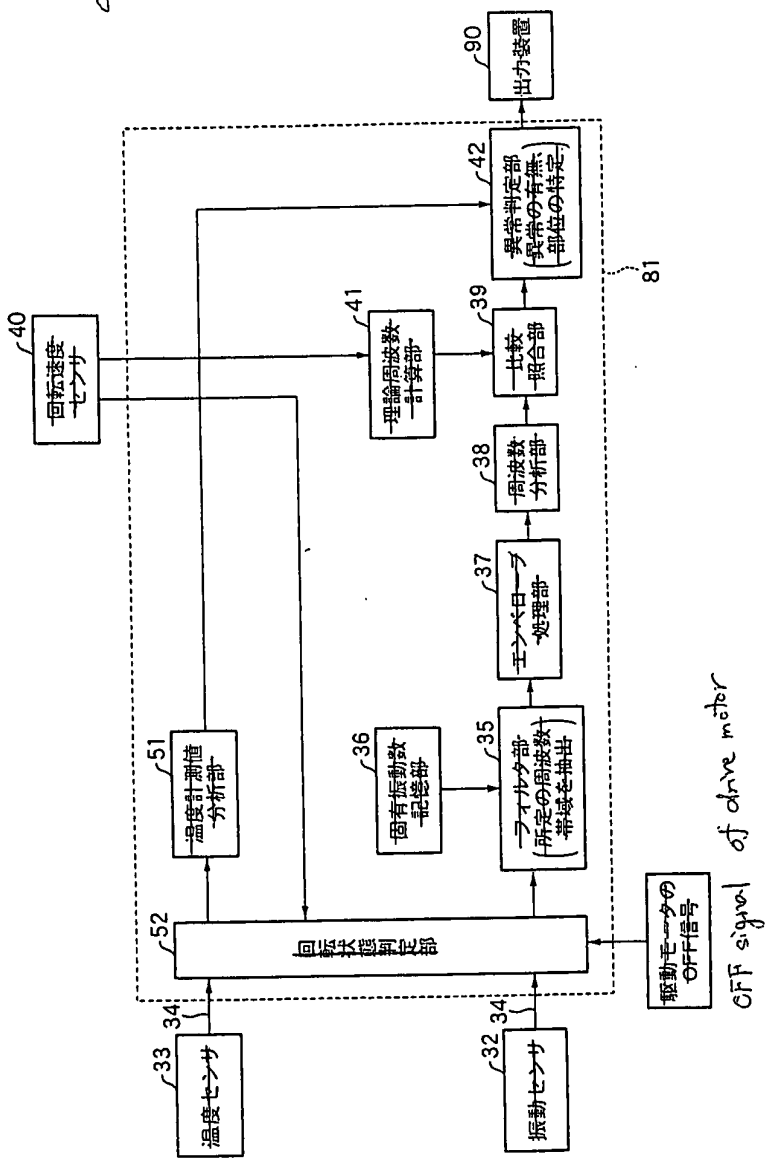


~~かみ合い周波数成分~~ mesh frequency component : $Sg=Z_1\times\frac{N_1}{60}$ or $Sg=Z_2\times\frac{N_2}{60}$

N_1 : ~~大歯車の回転数~~(min^{-1})
N_2 : ~~小歯車の回転数~~(min^{-1})
Z_1 : ~~大歯車の歯数~~
Z_2 : ~~小歯車の歯数~~

N_1: rotational speed of large gear (min^{-1})
N_2: rotational speed of small gear (min^{-1})
Z_1: teeth number of large gear
Z_2: teeth number of small gear

[図7] Fig. 7



[Fig. 7]

33 temperature sensor

32 vibration sensor

52 rotational state determining portion

51 temperature measured value analyzing portion

36 characteristic frequency storing portion

35 filter portion (for extracting predetermined frequency band)

37 envelope processing portion

38 frequency analyzing portion

40 rotational speed sensor

41 theoretical frequency calculating portion

39 comparing and checking portion

42 abnormality determining portion (for specifying presence or absence of abnormality, degree of damage, specification of portion)

90 outputting unit

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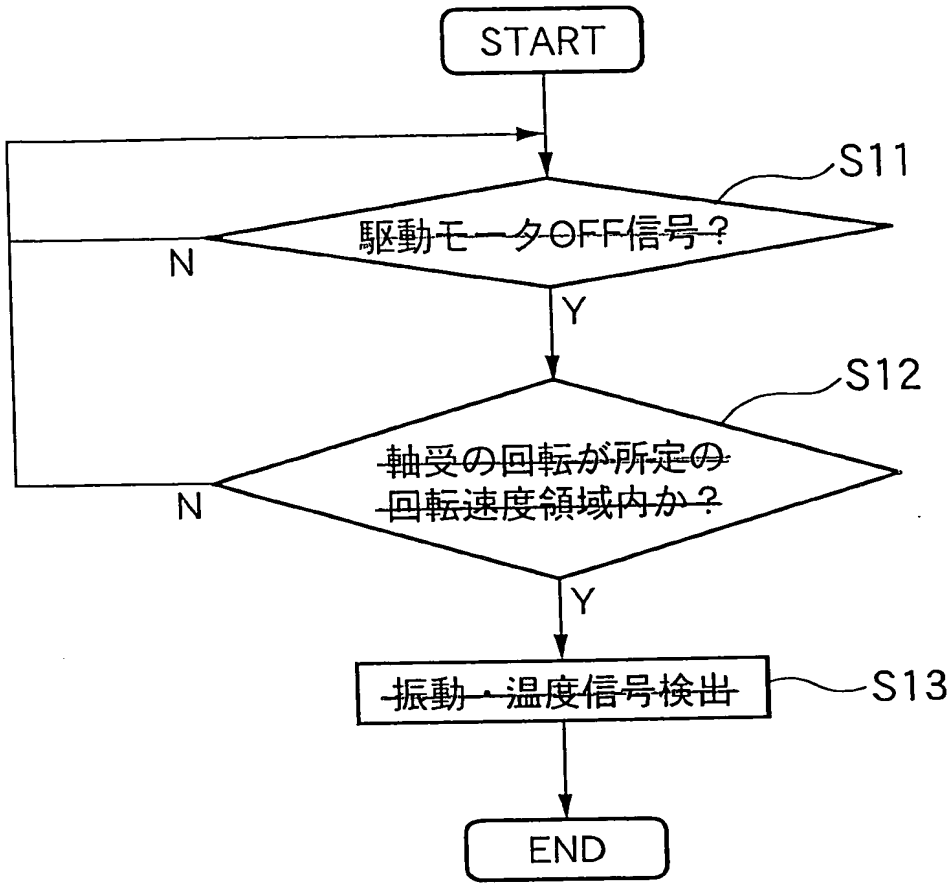
~~[図8]~~ Fig. 8



S11 drive motor OFF signal?

S12 rotation bearing is within predetermined rotational speed region?

S13 detect vibration/temperature signal

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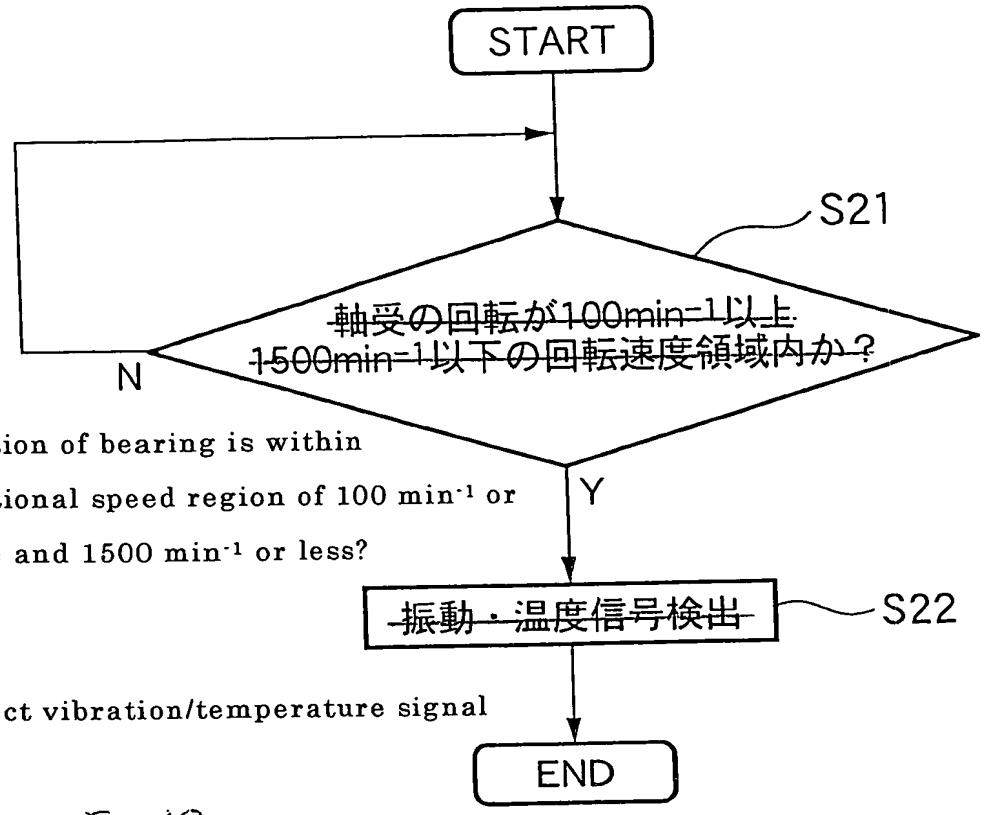
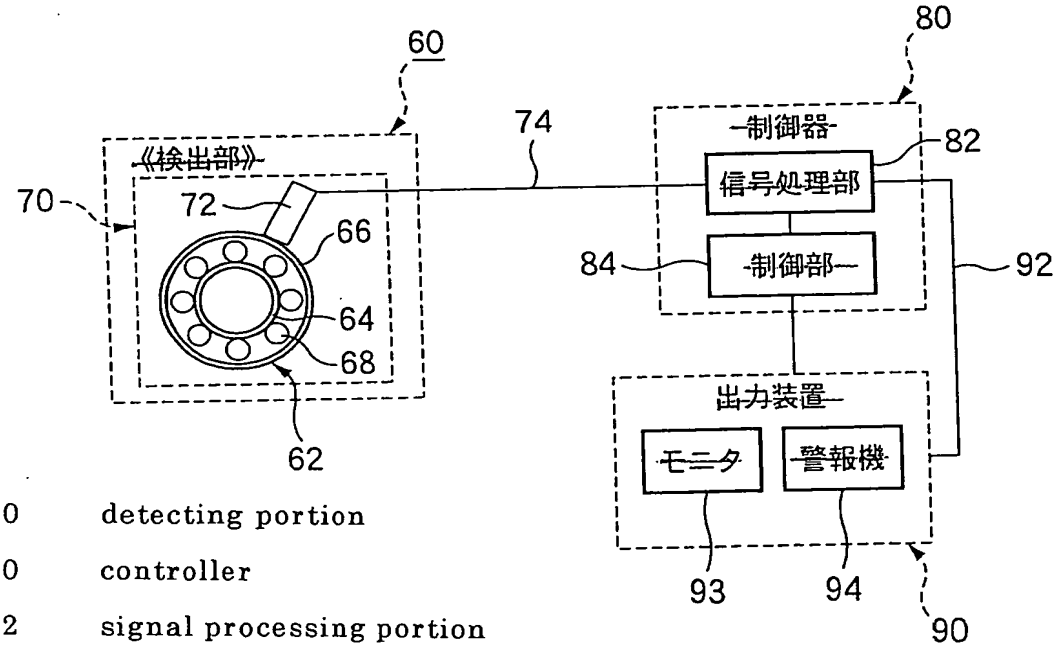
~~[図9]~~ Fig. 9



S21 rotation of bearing is within rotational speed region of 100 min^{-1} or more and 1500 min^{-1} or less?

S22 detect vibration/temperature signal

~~[図10]~~ Fig. 10



60 detecting portion
80 controller
82 signal processing portion
84 controlling portion
90 outputting unit
93 monitor
94 alarm

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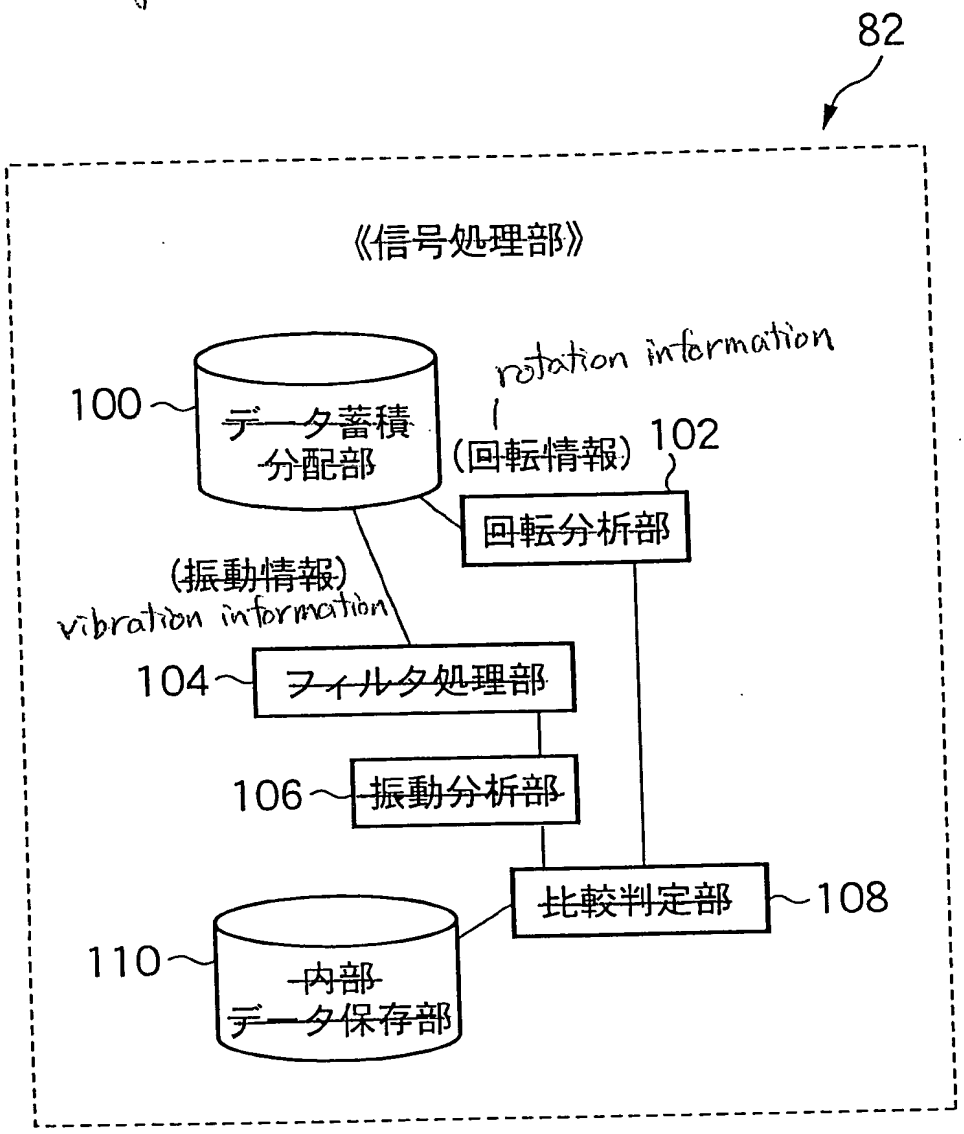
~~[図11]~~ Fig. 11



82 signal processing portion

100 data accumulating and distributing portion

102 rotation analyzing portion

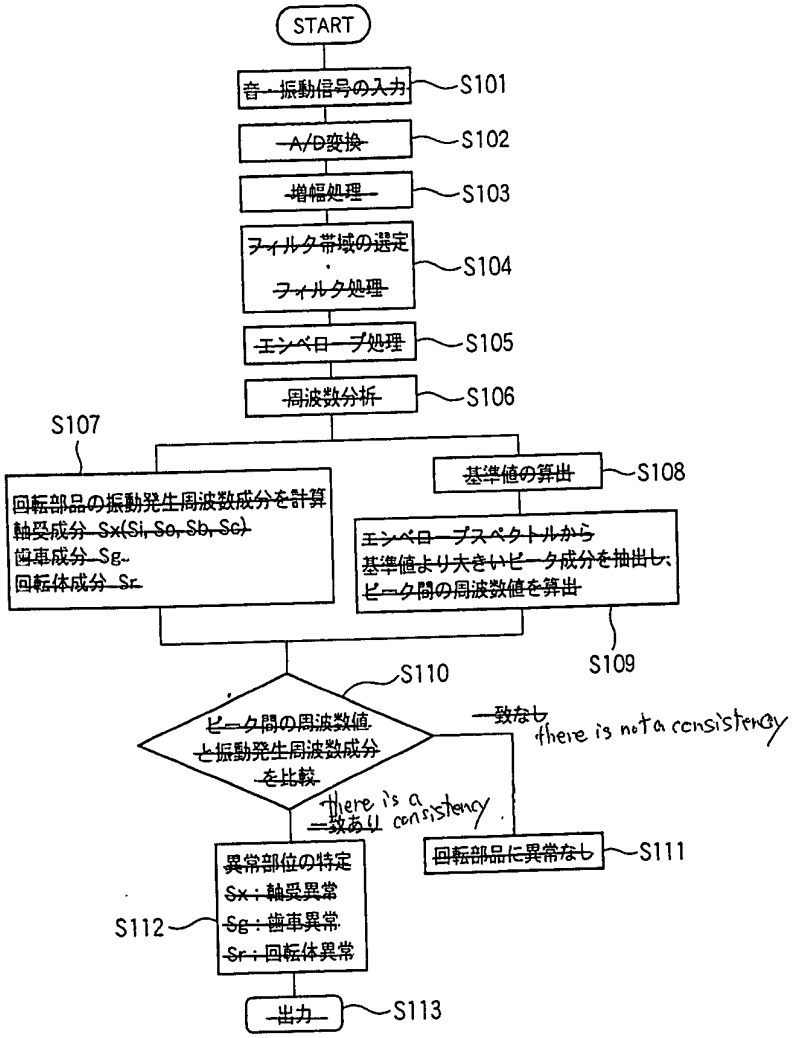
104 filter processing portion

106 vibration analyzing portion

108 comparing and determining portion

110 internal data holding portion

~~[図12]~~ Fig. 12



[Fig. 12]

S101 input sound/vibration signal

S102 A/D conversion

S103 amplifying processing

S104 select filter band and filter processing

S105 envelope processing

S106 frequency analysis

S107 calculate vibration generating frequency component of rotating part

bearing component Sx (Si, So, Sb, Sc)

gear component Sg

rotating member component Sr

S108 calculate reference value

S109 sample, peak component larger than reference value from envelope spectrum and calculate frequency value between peaks

S110 compare frequency value between peaks and vibration generating frequency component

S111 rotating member is not abnormal

S112 specify abnormal portion

Sx: bearing abnormal

Sg: gear abnormal

Sr: rotating member abnormal

S113 output

~~[図13]~~

Fig. 13

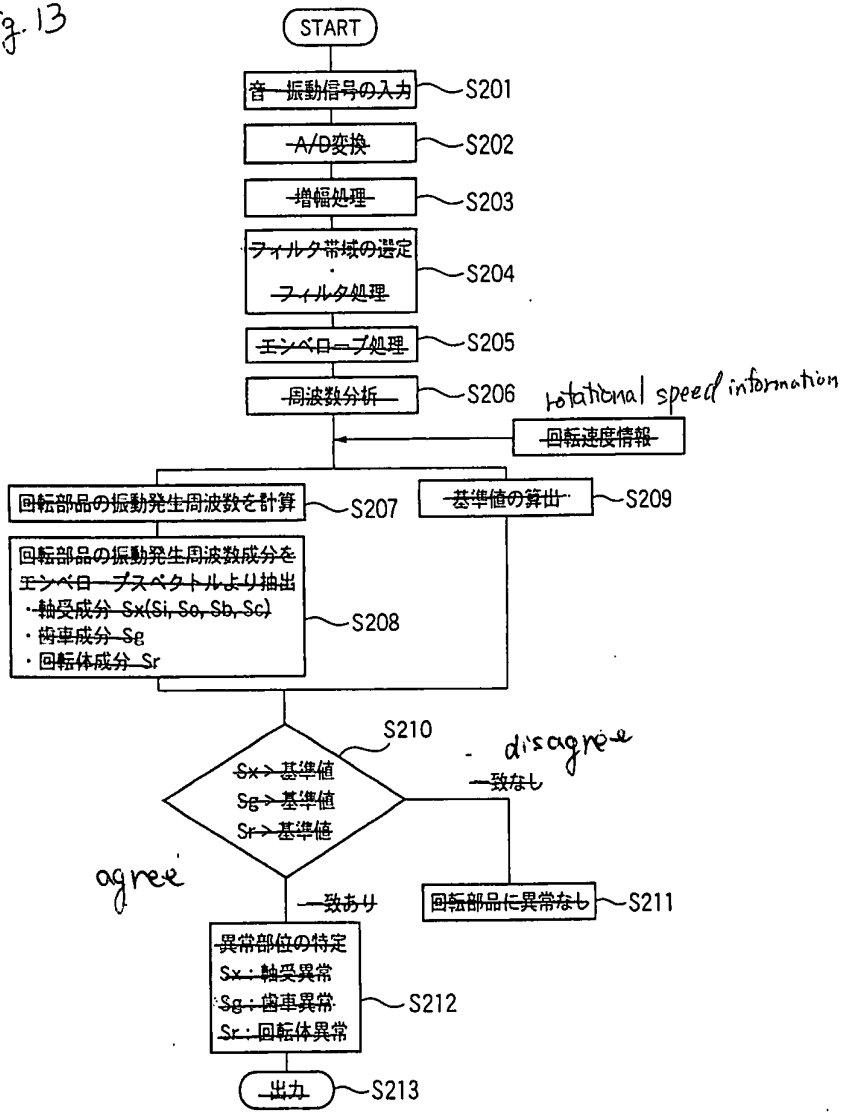


Fig.13

S201 input sound/vibration signal

S202 A/D conversion

S203 amplifying processing

S204 select filter band and filter processing

S205 envelope processing

S206 frequency analysis

S207 calculate vibration generating frequency of rotating part

S208 simple vibration generating frequency component of rotating part from envelope spectrum

- bearing component Sx (Si, So, Sb, Sc)
- gear component Sg
- rotating member component Sr

S209 calculate reference value

S210 Sx > reference value

Sg > reference value

Sr > reference value

coincidence

no coincidence

S211 rotating member is not abnormal

S112 specify abnormal portion

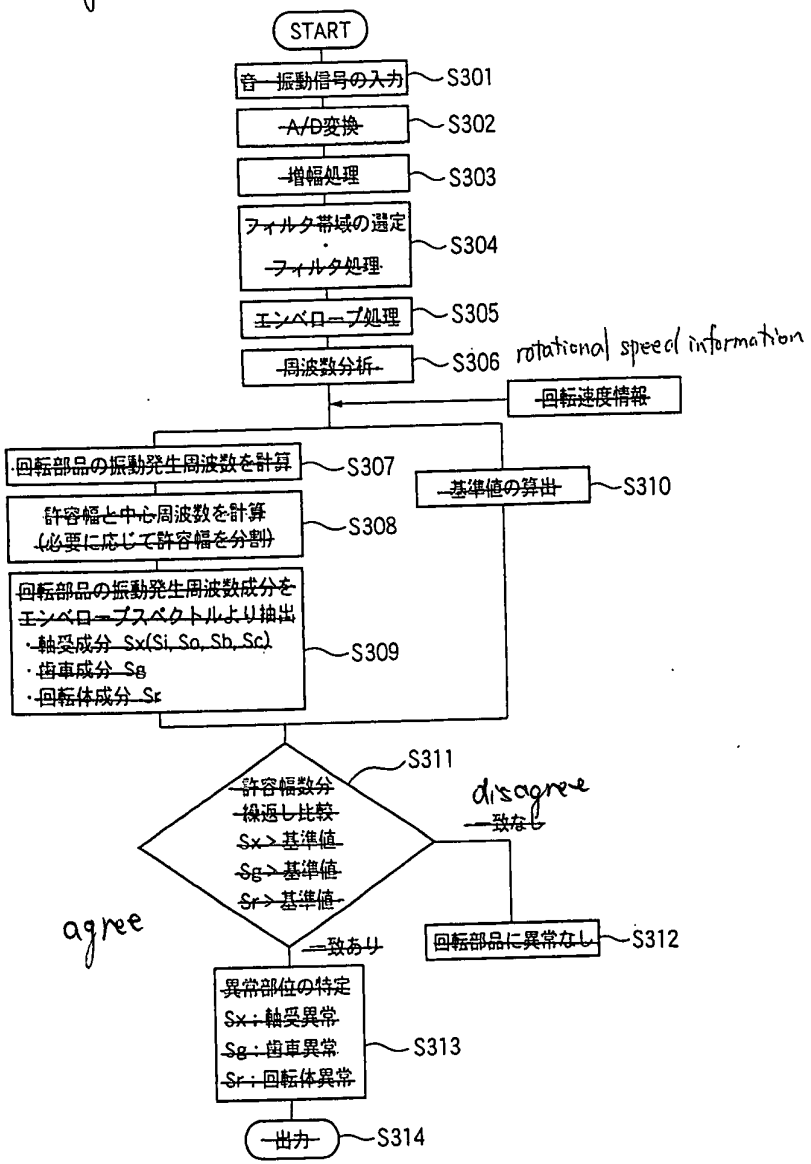
Sx: bearing abnormal

Sg: gear abnormal

Sr: rotating member abnormal

S113 output

~~[図14]~~ Fig. 14



[Fig. 14]

S301 input sound/vibration signal

S302 A/D conversion

S303 amplifying processing

S304 select filter band and filter processing

S305 envelope processing

S306 frequency analysis

S307 calculate vibration generating frequency of rotating part

S308 calculate allowable width and centrol frequency (divide allowable width as necessary)

S309 sample vibration generating frequency component of rotating part from envelope spectrum

bearing component Sx (Si, So, Sb, Sc)

gear component Sg

rotating member component Sr

S310 calculate reference value

S311 repeatedly compare amount of allowable width number

Sx > reference value

Sg > reference value

Sr > reference value

S312 rotating member is not abnormal

S313 specify abnormal portion

Sx: bearing abnormal

Sg: gear abnormal

Sr: rotating member abnormal

S314 output

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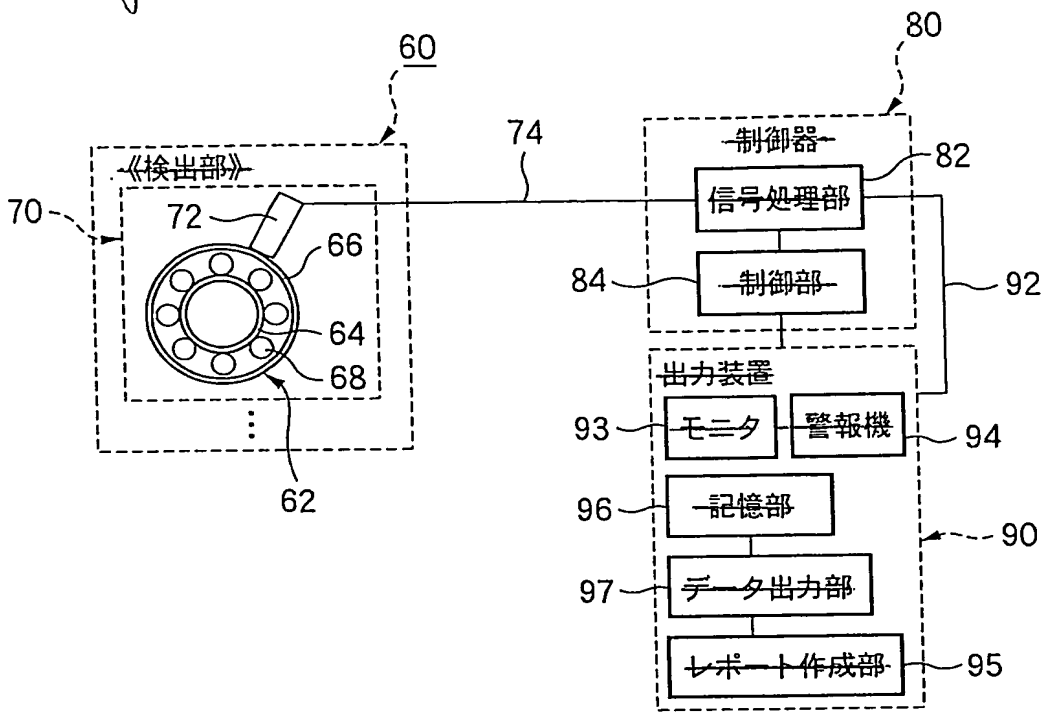
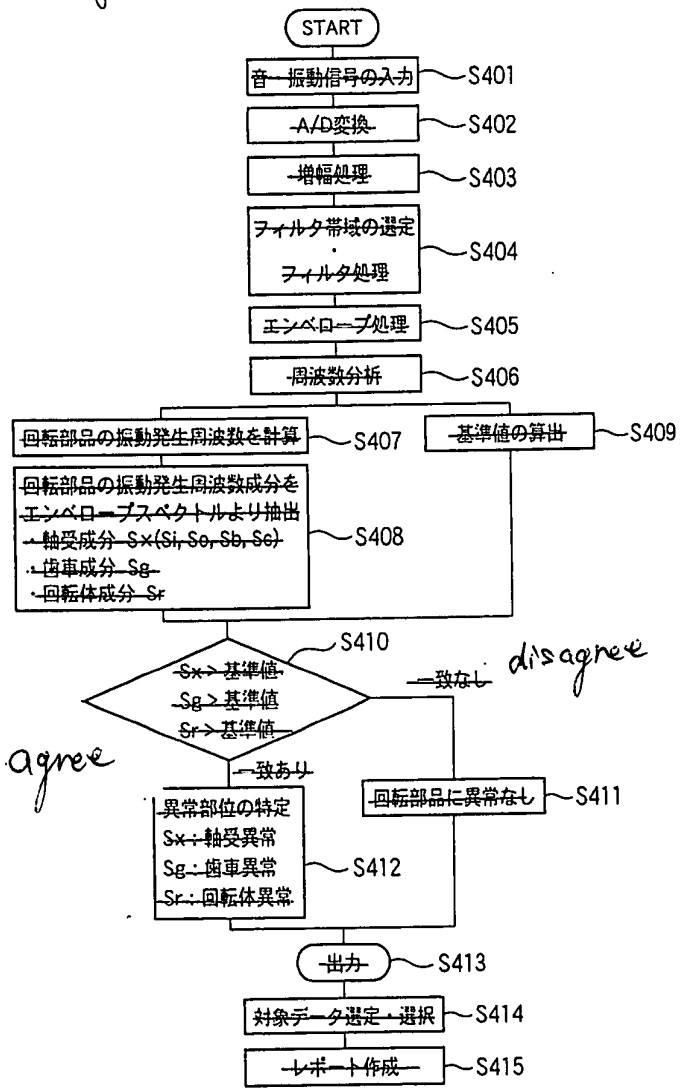
[図15] Fig. 15



60	detecting portion
80	controller
82	signal processing portion
84	controlling portion
90	outputting unit
93	monitor
94	alarm
96	storing portion
97	data outputting portion
95	report forming portion

~~[図16]~~ Fig. 16



[Fig. 16]

S401 input sound/vibration signal

S402 A/D conversion

S403 amplifying processing

S404 select filter band and filter processing

S405 envelope processing

S406 frequency analysis

S407 calculate vibration generating frequency of rotating part

S408 sample vibration generating frequency component of rotating part from envelope specter

- bearing component Sx (Si, So, Sb, Sc)
- gear component Sg
- rotating member component Sr

S409 calculate reference value

S410 Sx > reference value

Sg > reference value

Sr > reference value

S411 rotating part is not abnormal

S412 specify abnormal portion

Sx: bearing abnormal

Sg: gear abnormal

Sr: rotating member abnormal

S413 output

S414 select object data

S415 form report

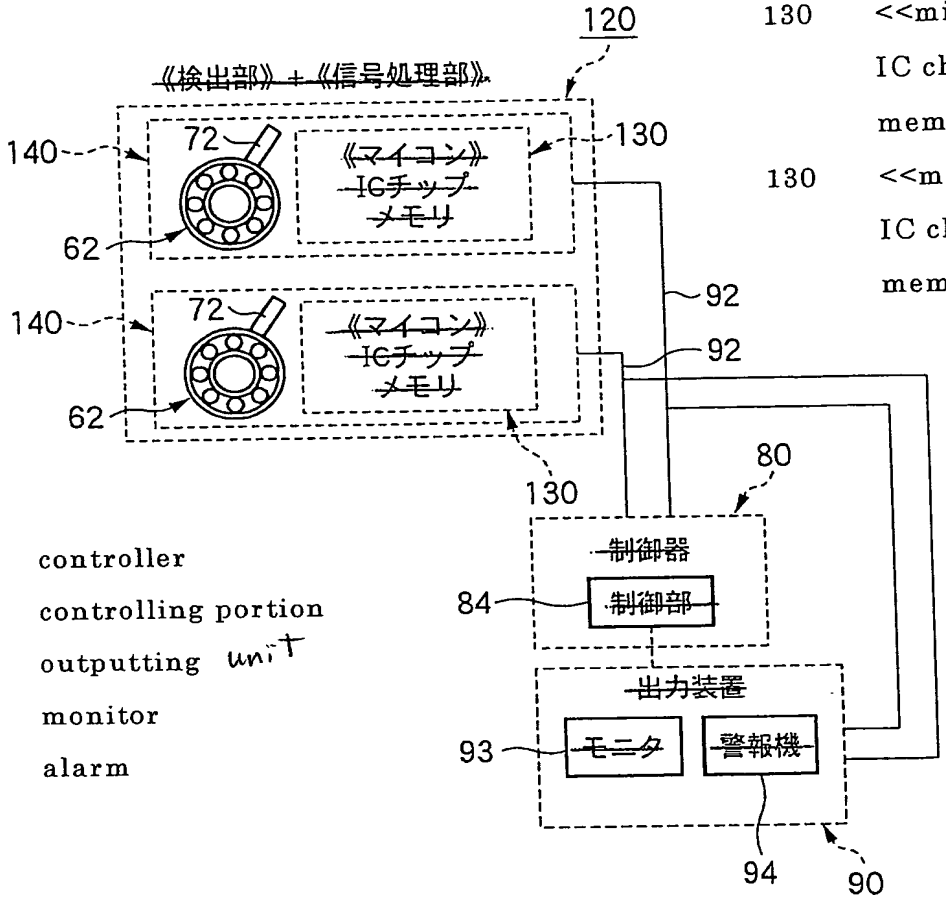
Fig. 17

~~[図17]~~

120 detecting portion + signal processing portion

130 <<microcomputer>> IC chip memory

130 <<microcomputer>> IC chip memory



80 controller

84 controlling portion

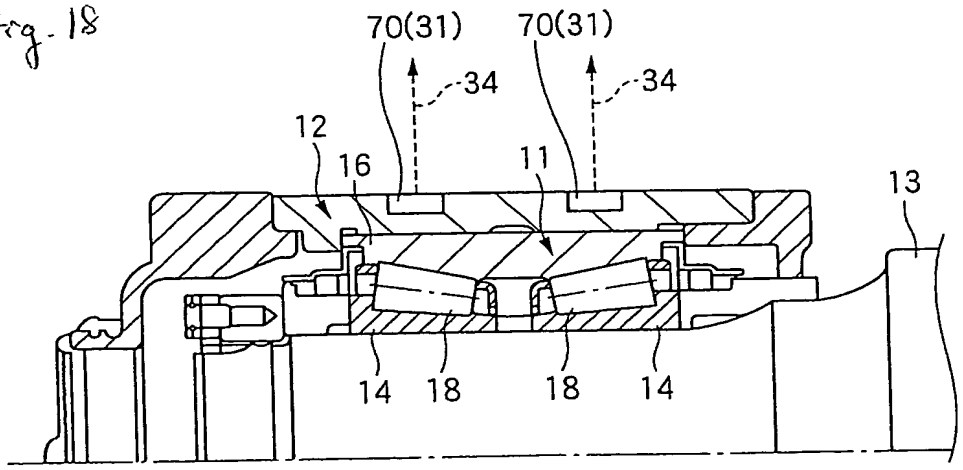
90 outputting unit

93 monitor

94 alarm

~~[図18]~~

Fig. 18



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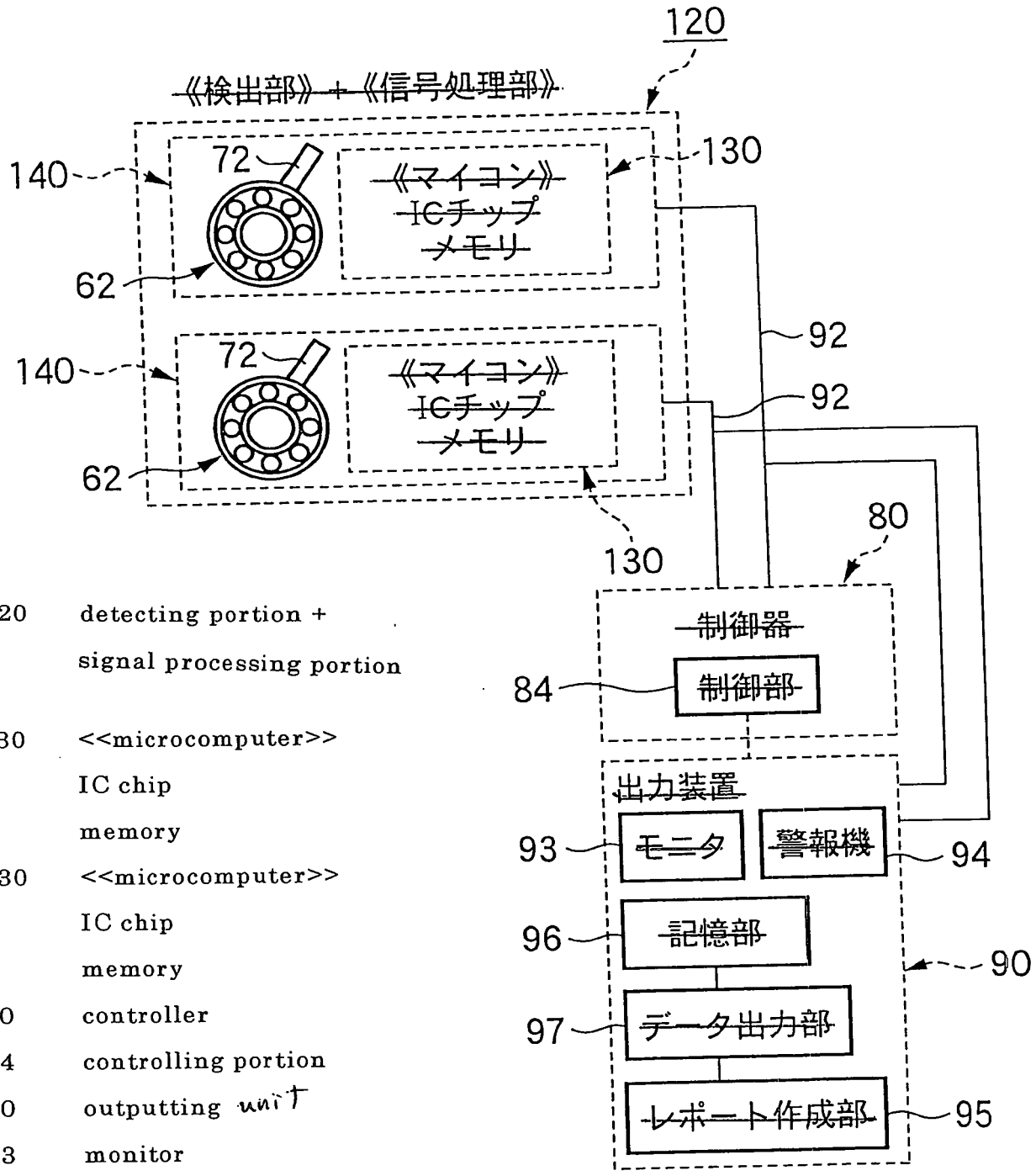
~~[図19]~~ Fig. 19



120	detecting portion + signal processing portion
130	<<microcomputer>> IC chip memory
130	<<microcomputer>> IC chip memory
80	controller
84	controlling portion
90	outputting unit
93	monitor
94	alarm
96	storing portion
97	date outputting portion
95	report forming portion

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~~[図20]~~ Fig. 20

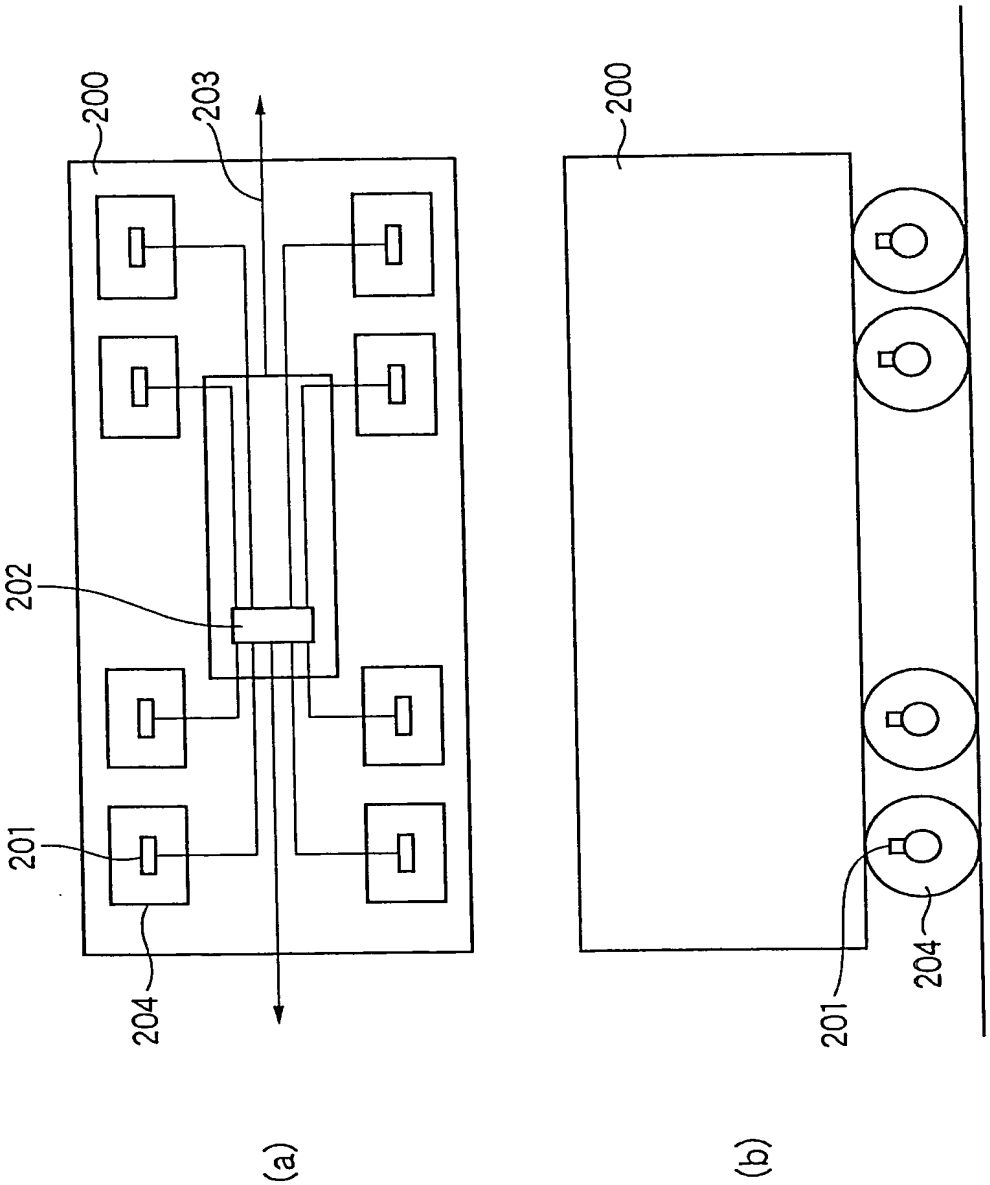

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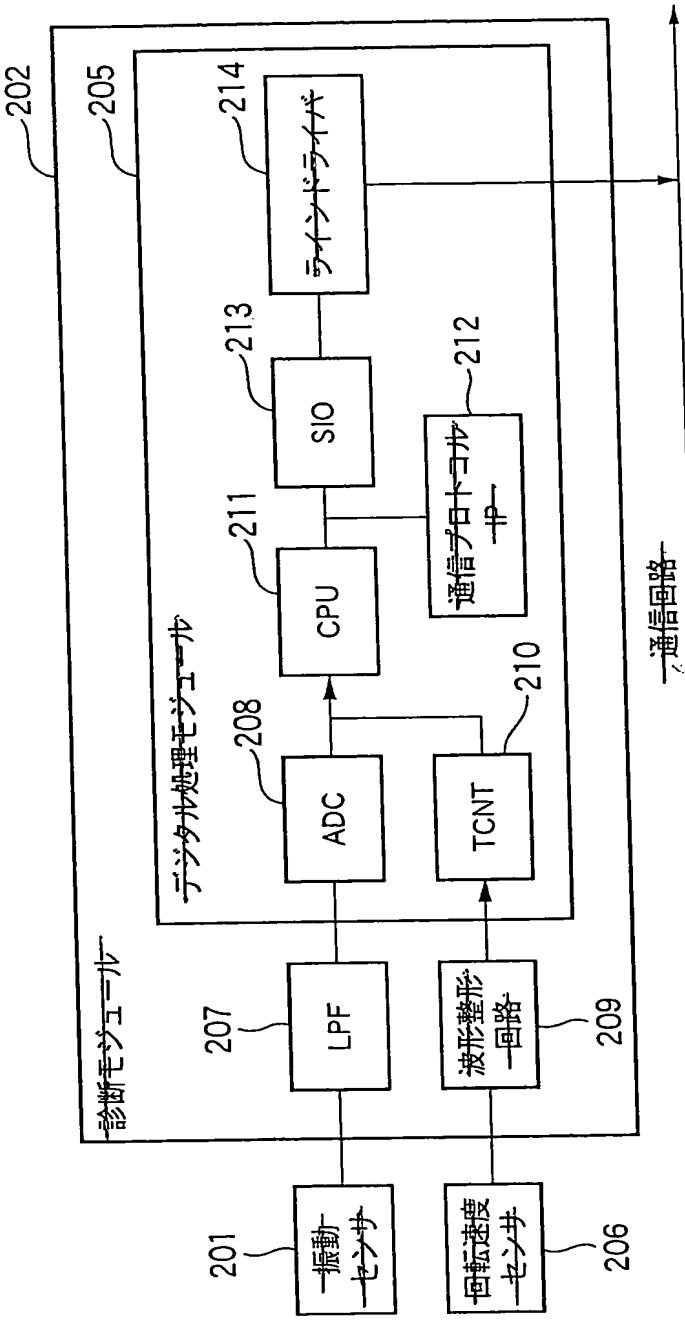
Fig. 21

~~[図21]~~



201 vibration sensor
206 rotational speed sensor
202 diagnosing module
205 digital processing module
209 waveform shaping circuit
214 line driver
212 communication protocol IP
communicating circuit

[Fig. 22]

S500 A/D conversion

S503 form absolute value

S504 hold to exceed threshold, time constant τ

S505 event count (count of number of times of exceeding threshold)

S506 coincide with wheel rotational number?

S507 internal output "F"

S508 external output "G"

S501 rotational speed changed by 15 % or more?

S502 internal output "N"

S509 output "F" by internal output consecutively by 3 times or more, or output "F" by 6 times or more in 10 times

S510 external output "Flat"

S511 external output "Good"

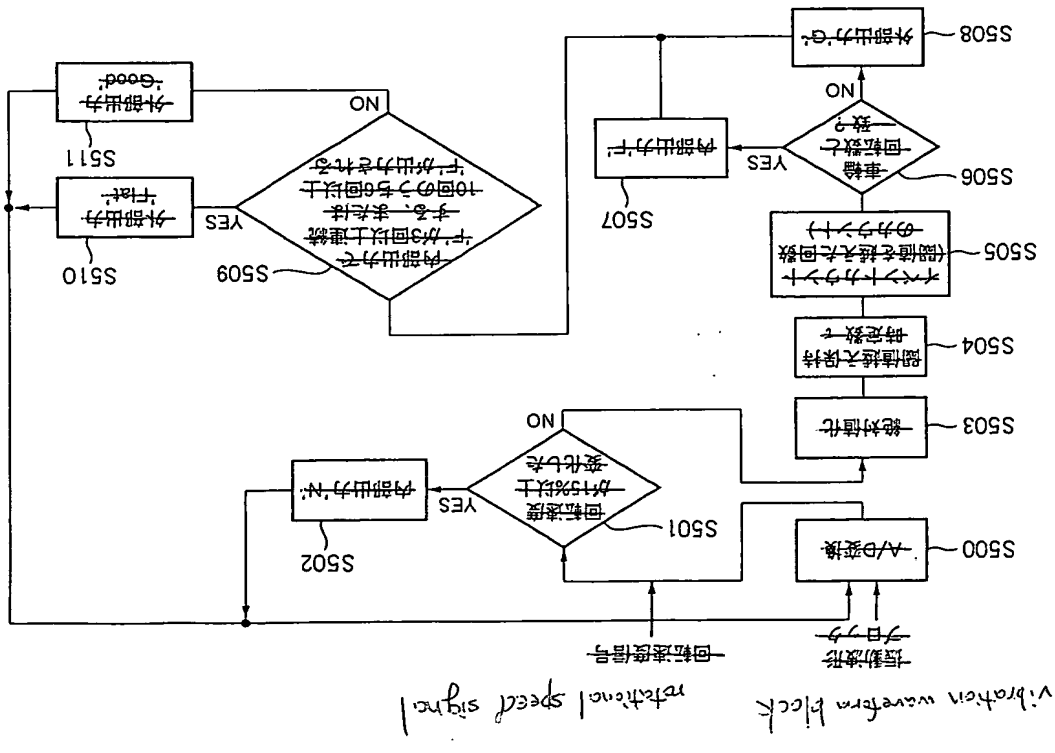


Fig. 22
従来

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Fig. 23A

~~[図23]~~

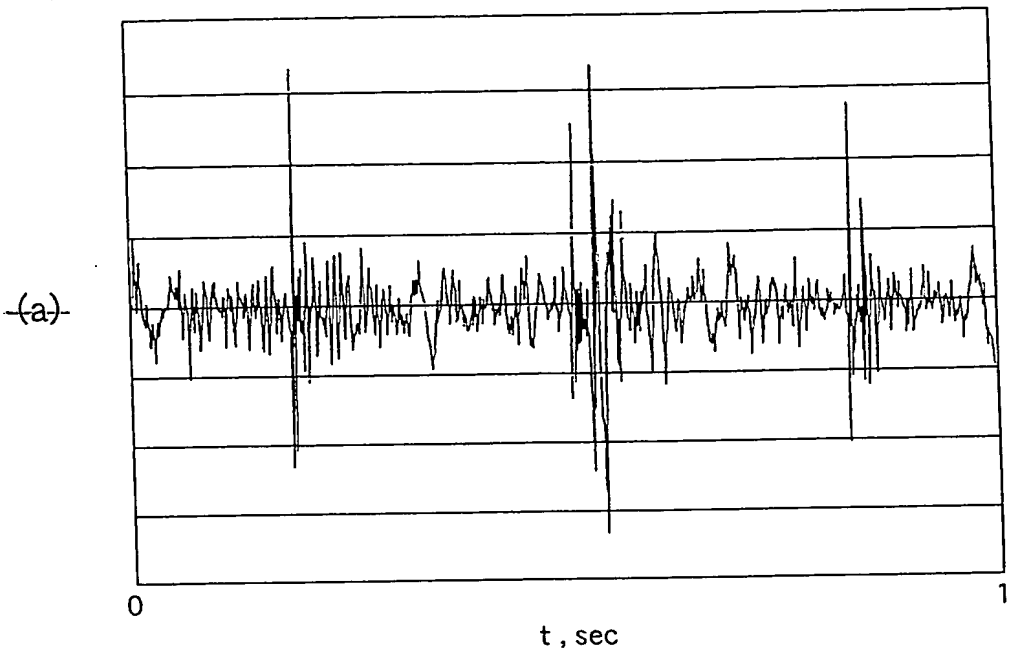

Fig. 23B

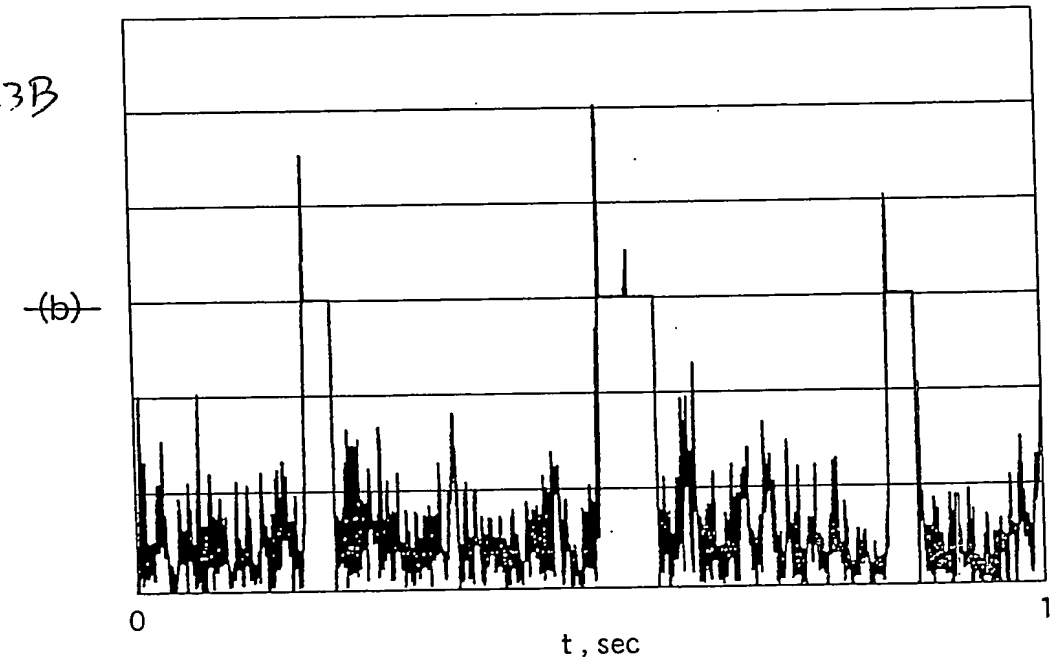

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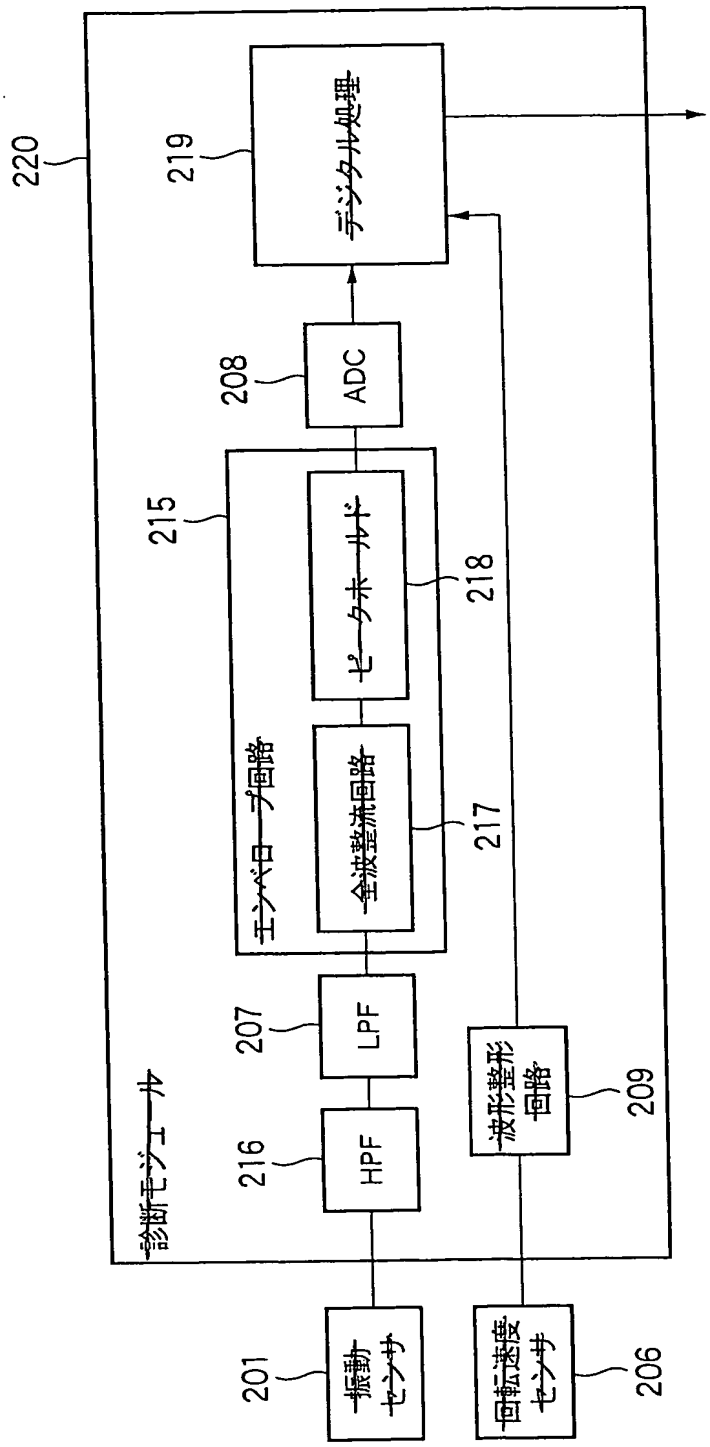
Fig. 24

[図24]



201 vibration sensor
206 rotational speed sensor
220 diagnosing module
209 waveform shaping circuit
215 envelope circuit
217 full wave rectified circuit
218 peak hold
219 digital processing

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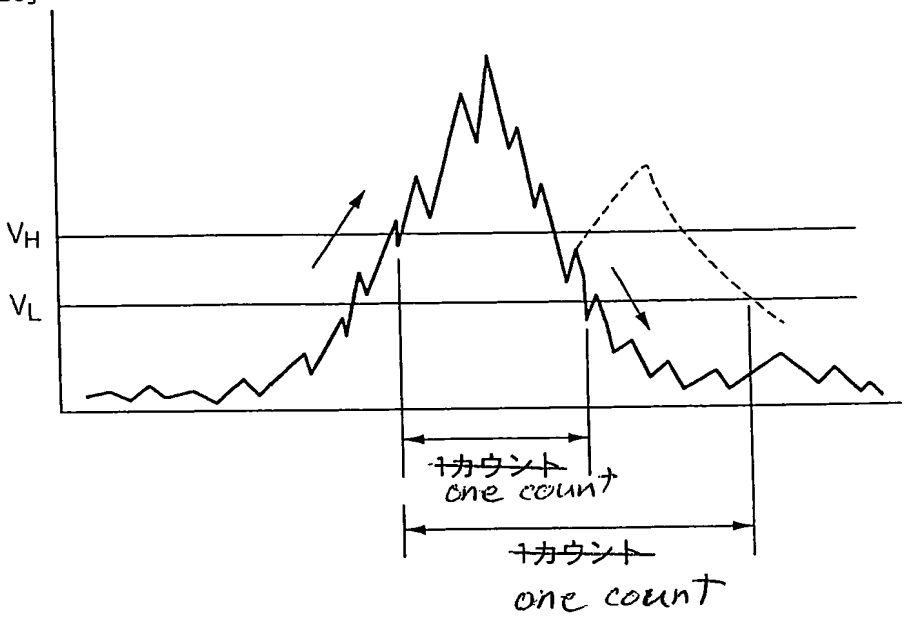
Fig. 25

~~[図25]~~



[図26]

Fig. 26

201	vibration sensor	232	envelop processing circuit
206	rotational speed sensor	233	Hilbert conversion
209	waveform shaping circuit	234	decode amplitude
230	diagnosing module	237	count threshold
231	digital processing portion	238	diagnose

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~~[図27]~~

Fig. 27A

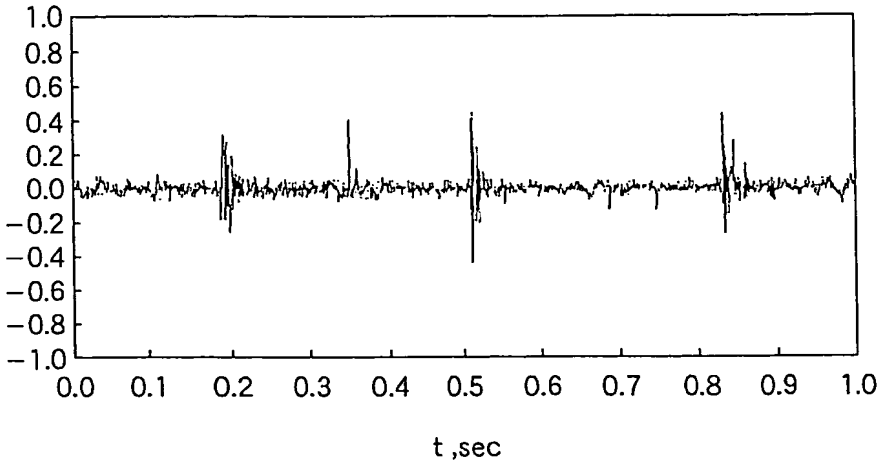
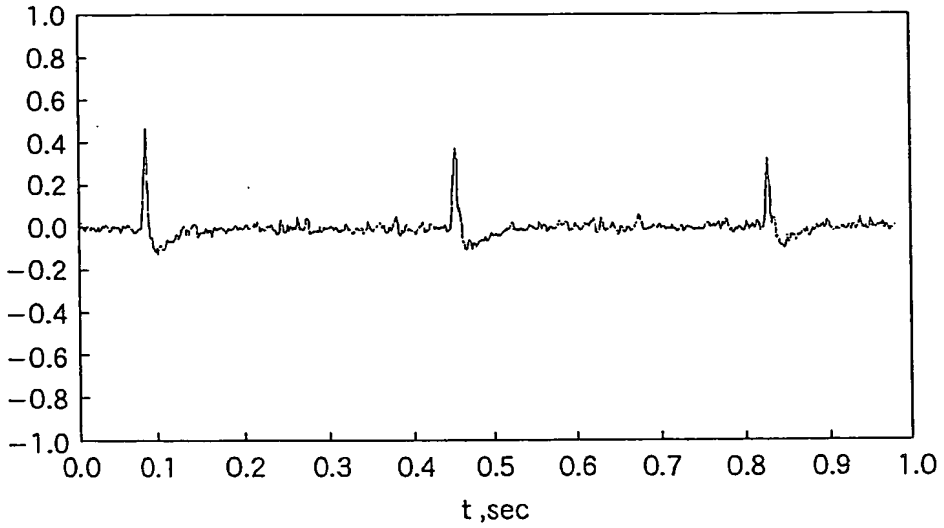


Fig. 27B



~~1秒間に3回の衝撃波が発生している~~
shock waves are generated by three times in one second.

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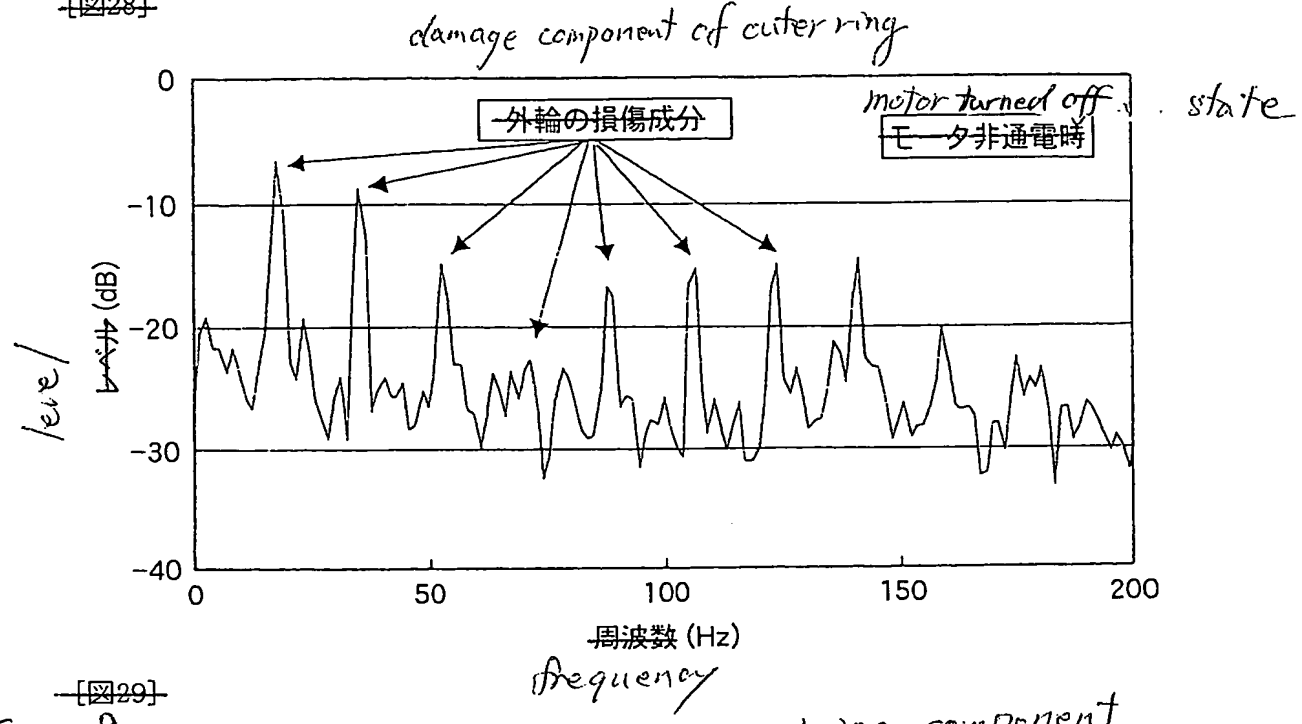
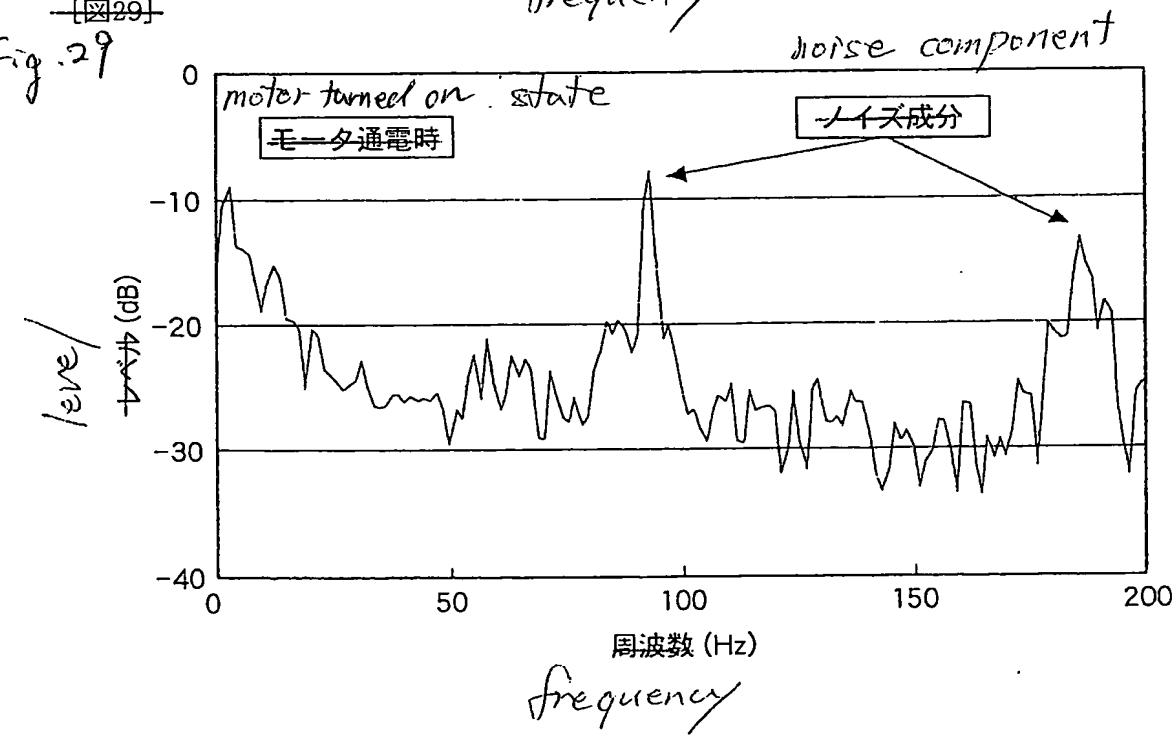
Fig. 28

~~[図28]~~



~~[図29]~~

Fig. 29



[Fig. 30]

(a) (1) bearing rotational speed: 50 min^{-1}

(b) (2) bearing rotational speed: 100 min^{-1}

(c) (3) bearing rotational speed: 150 min^{-1}

(d) (4) bearing rotational speed: 300 min^{-1}

(e) (5) bearing rotational speed: 650 min^{-1}

(f) (6) bearing rotational speed: 1000 min^{-1}

(g) (7) bearing rotational speed: 1500 min^{-1}

(h) (8) bearing rotational speed: 1600 min^{-1}

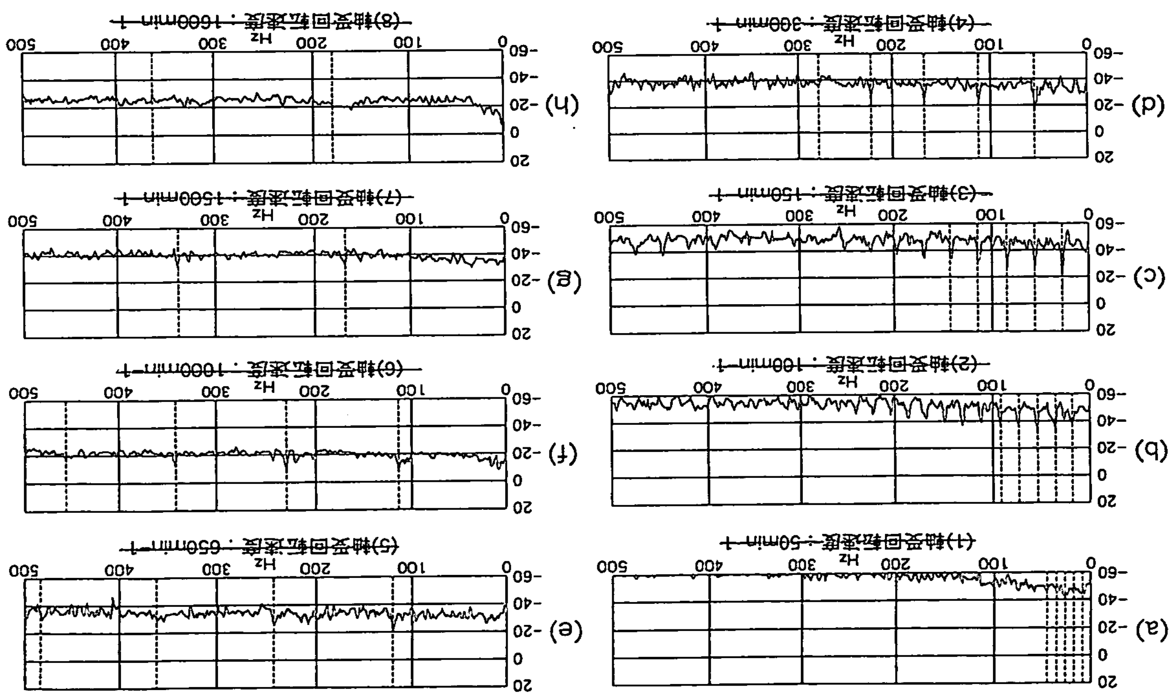


Fig. 30

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Fig. 31

~~[図31]~~

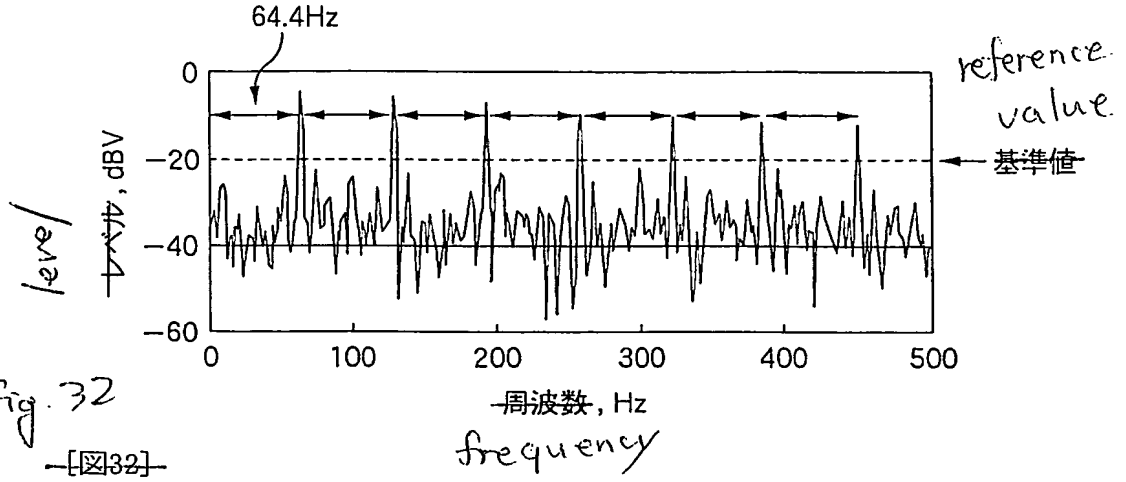

Fig. 32

~~[図32]~~

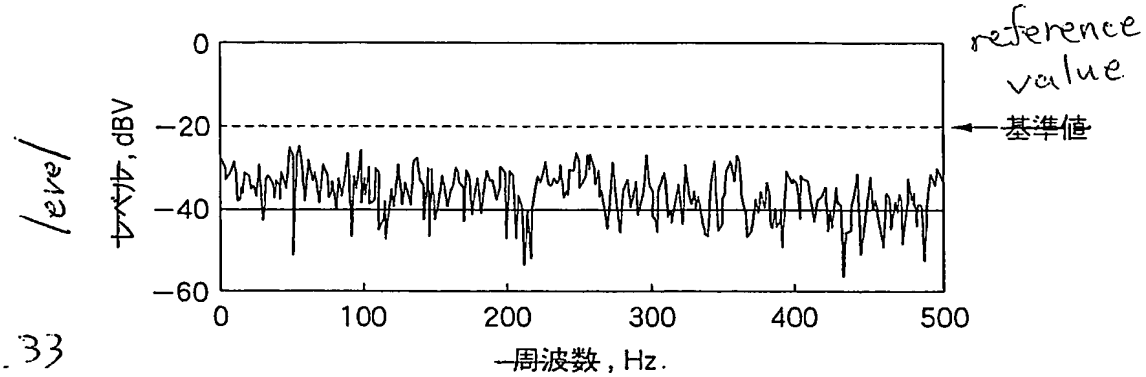

Fig. 33

~~[図33]~~

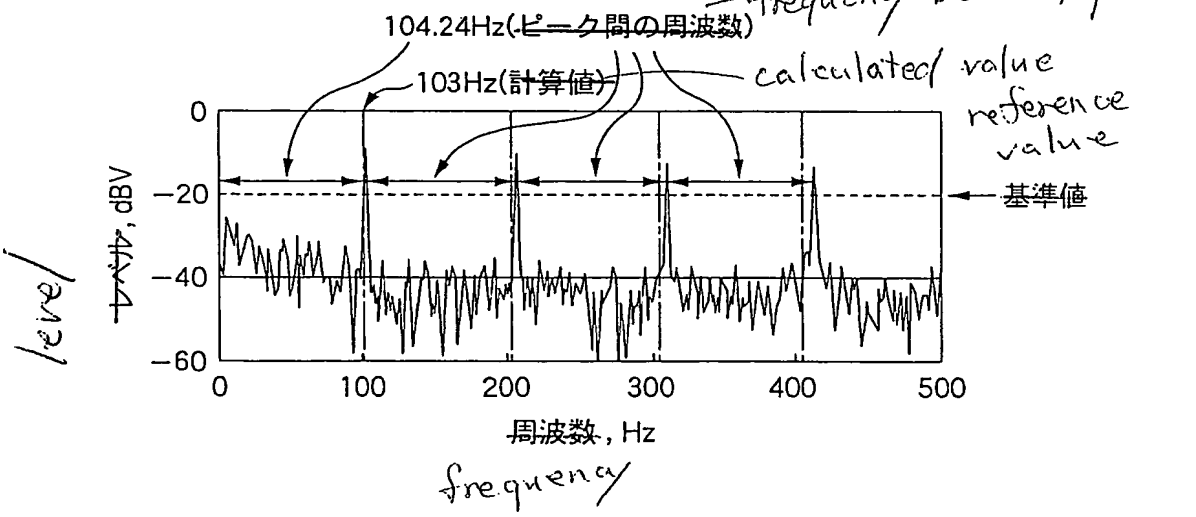

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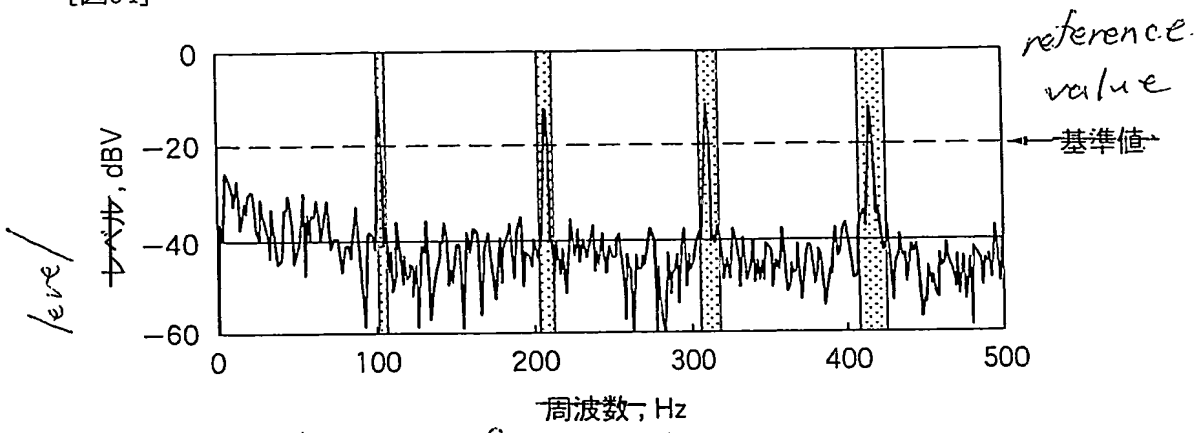
Fig. 34

~~[図34]~~



~~[図35]~~ Fig. 35

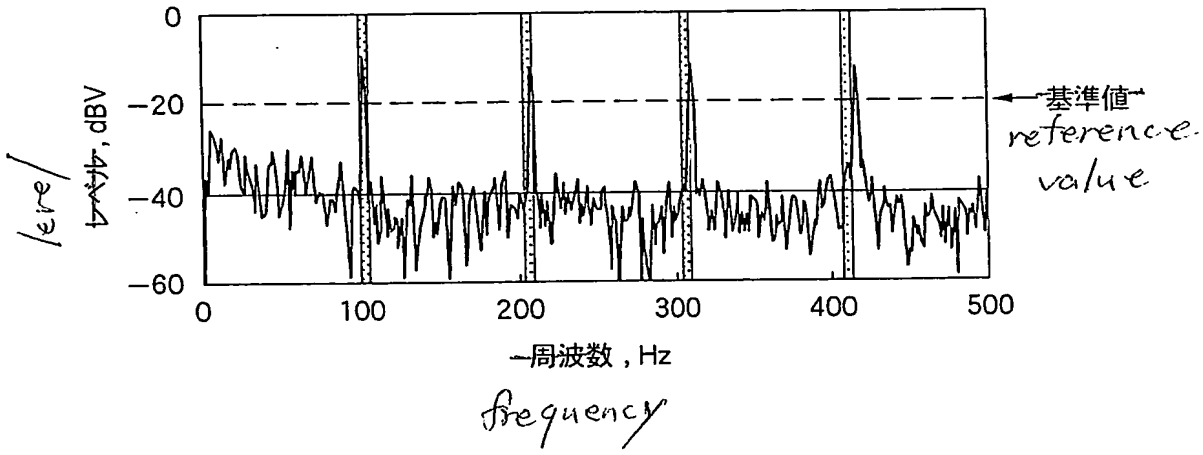


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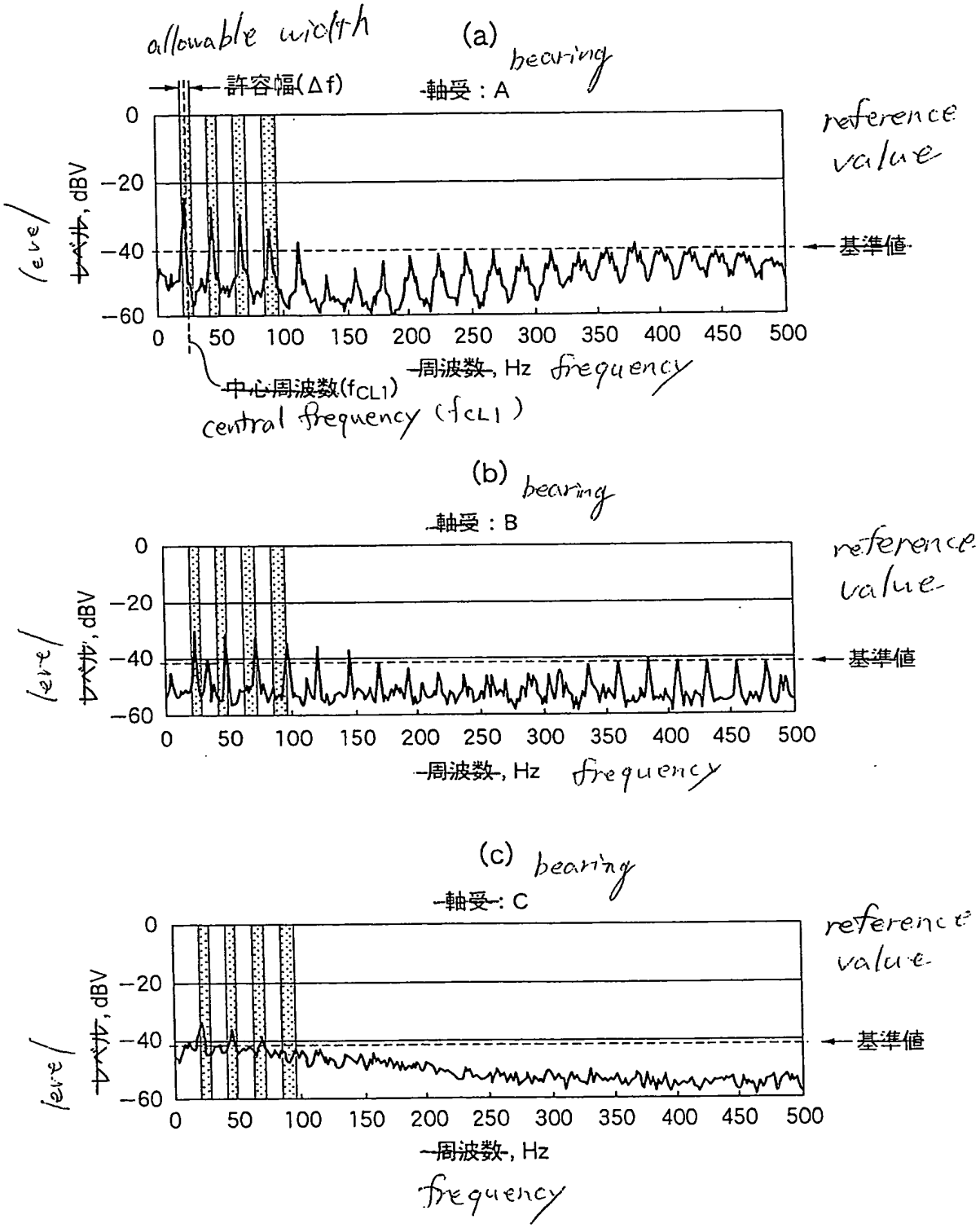
Fig. 36

~~[図36]~~



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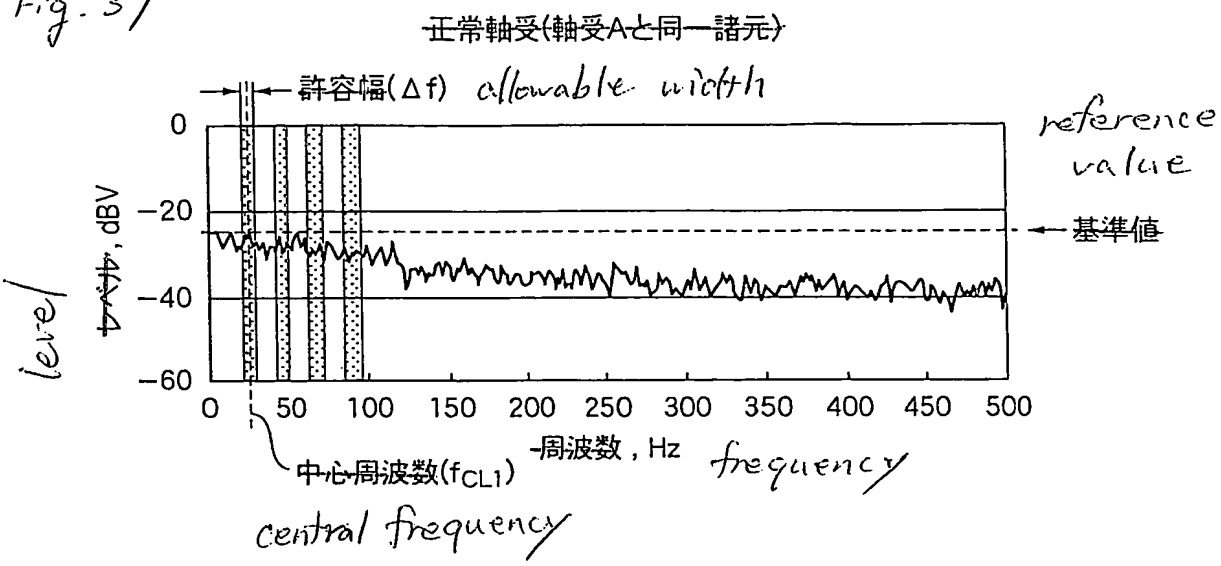
normal bearing
(same specifications as bearing A)

~~[図37]~~

Fig. 37



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[図38] Fig. 38

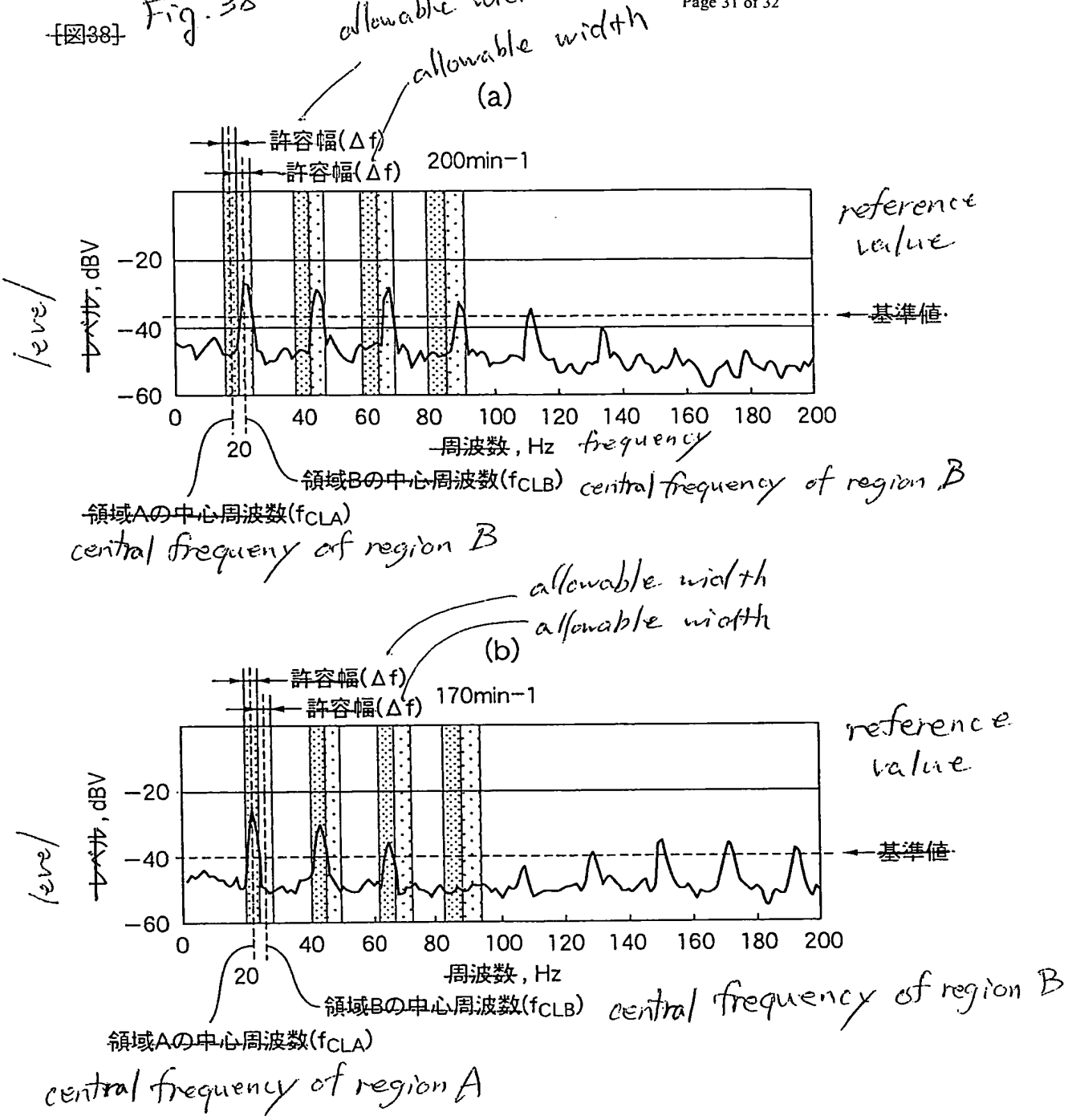

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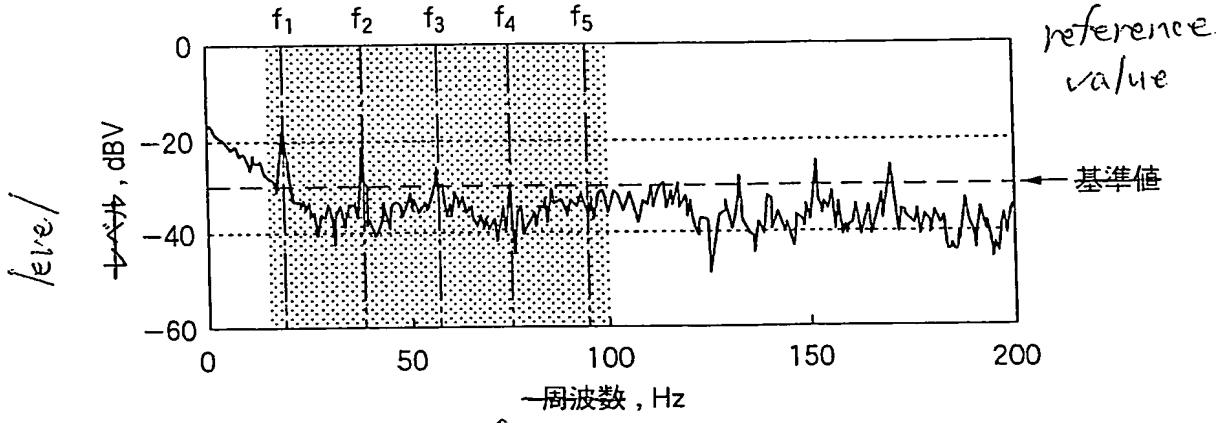
Fig. 39

~~[図39]~~



~~[図40]~~ Fig. 40